Impact of Biodiesel and its Blends with Diesel and Methanol on Engine Performance

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***Abstract*-Economic development in developing countries has led to huge increase in the energy demand. In India, the energy demand is increasing at a rate of 6.5% per annum. The crude oil demand of country is met by import of about 70%. Thus the energy security has become key issue for our country. Biodiesel, as an ecofriendly and renewable fuel substitute for diesel has been getting the attention of researchers all over the world. The research has indicated that upto B_{20}, there is no need of any modification. The aim of the present paper is to evaluate the engine performance using pure biodiesel and its blends. Also blends of pure Jatropha curcas oil with petro diesel and methanol is used in the present study to show their effect on engine performance in terms of brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE). From the results it is found that brake specific fuel consumption for B_{100} was 14.8% higher than diesel. The brake thermal efficiency is found higher upto B_{30} in comparison to diesel while BTE of B_{100} (24%) was almost equals to diesel (24.5%) for Jatropha oil methyl ester (JOME)**

Keywords-Biodiesel, Jatropha, Engine performance, Diesel.

I. INTRODUCTION

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of bioenergy, it has provided an effective way to fight against the problem of petroleum scarce and the influence on environment.

Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated. Although many researches pointed out that it might help to reduce green house gas emissions, promote sustainable rural development, and improve income distribution, there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduce of engine power for biodiesel, as well as the increase of fuel consumption, is not as much as anticipated; the early research conclusions have been kept in many people's mind, that is, it is more prone to oxidation for biodiesel which may result in insoluble gums and sediments that can plug fuel filter, and thus it will affect engine durability.

Although there are an increasing number of literatures to research engine performances and its emissions when using biodiesel, especially in this decade, only fewer people have analyzed and reviewed them. A previous review published by Graboski and McCormick [1] in 1998 could not reflect the new research achievements this decade, and the newer review finished by Lapuerta et al. [2] in 2008 did not include knowledge about engine durability, and about 20% literatures before 2000 year was cited to clarify the effect of biodiesel on engine performances and emissions. But the other newer one, written by Basha et al. [3] in 2009, seems unconvincing for professional (especially about the review on the long-term biodiesel engine test) and uneasy for non-professional to read.

According to analysis and summary in this work, it is helpful [1] for researchers and engine manufacturers to develop the further researches related to optimize and readjust biodiesel engine and its relevant systems; and [2] for governments to design new energy policies to impel the use of biodiesel in the light of environmental costs; and [3] for private users to understand profits for using biodiesel, and enhance consciousness of environmental protection. Engine performances for biodiesel such as power performance, economy performance and durability are introduced and summarized at considerable length in Section 2. Then, the regulated emissions such as PM (particulate matter), NOx (nitrogen oxides), CO (carbon monoxide), HC (hydrocarbon), and CO2, and non-regulated emissions such as aromatic and polyaromatic compounds and carbonyl compounds, are listed to survey detailedly in Section 3. Finally, conclusions are drawn and further researches are pointed out.

Content of biodiesel blended with diesel results in the difference in engine power performance, which has become the commonsense.

Engine power will decrease with the increase of content of biodiesel [4- 18]. For example, Carraretto et al. [12]found that the increase of biodiesel percentage in the blends resulted in a slight decrease of both power and torque over the entire speed range for different blends (B20, B30, B50, B70, B80, B100) of biodiesel and diesel on a 6-cylinder DI diesel engine. Aydin et al. [4] reported that the torque was decreased with the increase in CSOME (cottonseed oil methyl ester) in the blends (B5 B20 B50 B75 B100) due to higher viscosity and lower heating value of CSOME. And Murillo et al. [8] observed that increasing the amount of biodiesel in the fuel decreased engine power on a single-cylinder, 4-stroke, DI and NA diesel engine.

Gumus and Kasifoglu [19] found the power increased with the addition of biodiesel content in the blends until the B20 blend and reached a maximum value, when the biodiesel

content continued to increase in the blends, the power would decrease below that of the diesel fuel and reached minimum value for B100, which was obtained on a single-cylinder, 4-stroke, DI, air-cooled (AC) diesel engine. Likewise, Usta et al. [20] showed that the power initially increased with the addition of biodiesel, reached a maximum value, and then decreased with further increase of the biodiesel content.

II. MATERIAL & METHODS

The fuel properties of Jatropha curcas oil (JCO) are mentioned in table 1 showing the high amount of FFA contents therefore biodiesel was prepared using 2 step acid base catalyzed transesterification processes developed by the authors and reported in our previous publications [21 and 22]. A brief summary of the method of biodiesel preparation is discussed in experimental section. Physico- chemical properties of JCB is given in table 2.

Table 1: Fuel Properties of *Jatropha curcas* oil

S.No.	Properties	*Jatropha curcas* oil
1	Density (kg/m^3 @ 15 °C)	935
2	Viscosity (cSt, @ 30 °C)	51
3	Flash point (°C)	235
4	FFA contents (%)	15.4
5	Gross calorific value (MJ/kg)	37.98

Table 2: Physico- chemical properties of biodiesel as per different standards

S.No.	Property (unit)	IS 15607	IS 15607 limits	Jatropha ME
1	Flash point(^{0}C)	IS 1448		172
2	Viscosity at 40^{0}C(cSt)	IS 1448		4.38
3	Water and sediment (vol%)	D-2709	Max.0.05	0.05
4	Free glycerin (% mass)	D-6584	Max.0.02	0.01
5	Total glycerin (% mass)	D-6584	Max.0.24	0.03
6	Oxidation stability of FAME, hrs	EN 14112	Min. 6	3.27
7	Oxidation stability of FAME blend, hrs	EN 590	Min. 20	-
8	Free glycerol	D6584	0.02 max)	0.01
9	Total glycerol	D6584	0.25(max)	0.12
10	Acid value	D664	0.5(max)	0.38
11	Ester content	EN14103	96.5(max)	98.5

III. EXPERIMENTAL

A. Biodiesel preparation

Since the initial free fatty acid (FFA) contents of JCO was very high (15.4%) as shown in table 1 therefore a two step acid- base catalyzed transesterification process is used to prepare biodiesel [21] and [22]. H2SO4 is selected as acid for esterification, KOH is selected as base for transesterification and methanol is selected as alcohol for both the reactions. After completion of the reaction, the reaction mixture was transferred to separating funnel and both the phases were separated. Upper phase was biodiesel and lower phase contained glycerin. Alcohol from both the phases was distilled off under vacuum. The glycerin phase was neutralized with acid and stored as crude glycerin. Upper phase i.e. methyl ester (biodiesel) was washed with the water twice to remove the traces of glycerin, unreacted catalyst and soap formed during the transesterification. Fatty acid composition of biodiesel was analyzed using gas chromatograph [23].

The samples were analyzed for ME formation at a pre-determined interval of time by Gas Chromatograph (Netal make) equipped with a flame ionization detector and a capillary column for injecting the sample. The GC oven was kept at 230°C (5°C/ min). Nitrogen was used as carrier gas. Quantitative analysis of% ME was done using European standard EN 14,103:2003 (DIN EN, 1410). The% ME yield was calculated using Eq. (1). Free fatty acids in the samples were determined using stock solution (Methyl heptadecanoate and n- heptane).

$$\% \text{ of ME} = \frac{\Sigma A - A_{EI}}{A_{EI}} X \frac{C_{EI} - V_{EI}}{m} X100 \tag{1}$$

AEI = Peak area corresponding to methyl heptadecanoate;

CEI = Concentration of the to methyl heptadecanoate solution (mg/ml);

VEI = Volume of the to methyl heptadecanoate solution (ml);

m = Mass of the sample (mg).

B. Performance evaluation of IC engine

In order to study the performance of IC engine using biodiesel and its blends with diesel, an experimental study has been carried out. The efficiency and brake specific fuel consumption (BSFC) of the engine was measured under variable load conditions for different blends. Experimental procedure The engine was directly coupled with 2KVA alternator and loaded by electrical resistance. The separate fuel measurement unit was connected with engine. A resistive load panel was attached with the output of the generator. The engine- generator set was run initially using diesel for 10 minutes at each part load of 25%, 50%, 75% and 100% of 2 kW respectively. At each case, the rpm of the generator was maintained at 1500. The fuel consumption at each case was measured by using stopwatch. At the same time the reading of voltmeter, current meter and energy meter were also noted down. Different blends of biodiesel from JCO with diesel were prepared namely B10, B20, B30, B40, B50, and B100.Before using blend, each one was mixed thoroughly. Then in the similar manner as in case of diesel fuel reading of each meter is noted down. During each blend, the filter of diesel engine was opened and complete mixture of biodiesel and diesel was drained so that it could not impure next blend by mixing with its previous blend. Then again for another blend, in the similar fashion, the experiment was repeated for knowing the above stated parameters. In this way continuously one month, the experiments were performed for all type of blends as stated above.

IV. RESULTS AND DISCUSSION

A. BSFC for Blends of JCB and Diesel

The brake specific fuel consumption (BSFC) decreases as the load on the engine increased for all type of fuel combinations. The possible reason may be that, at lower loads, significant proportion of the fuel inducted through the intake does not burn completely due to lower quantity of pilot fuel,

low cylinder gas temperature and lean fuel air mixture. Another reason may be that at higher load, the cylinder wall temperature is increased, which reduces the ignition delay. Due to which the combustion improves and fuel consumption reduces. The trend of BSFC for different blends for biodiesel from Jatropha up to B100 is shown in fig.1, which indicates that the highest BSFC for B100 (401 g/kWh) at full load is about 14.8% higher than diesel (349 g/kWh). The reason for this is lower calorific value of JOME than diesel (around 12-13%).

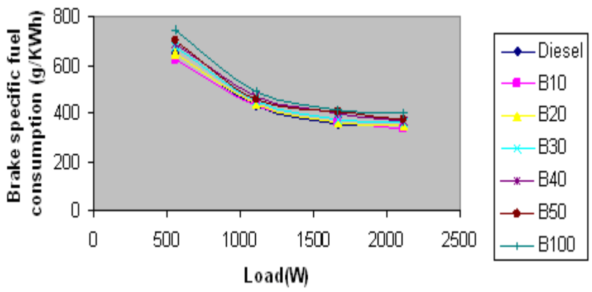
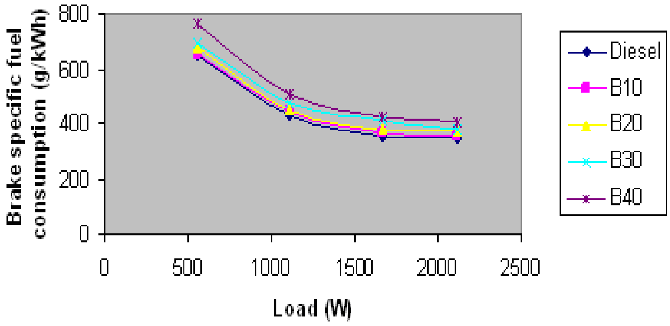


Fig.1 Variation in BSFC for Blends of JCB and Diesel

As the BSFC is depends on fuel specific gravity, viscosity and NCV therefore as the specific gravity increases and NCV decreases, more amount of fuel is needed to produce the same amount of energy. Therefore as the JOME proportion is increases in the blend, BSFC will also get increased. As it is clear from the results BSFC for B10 (335 g/kWh) which is 4% less than diesel, for B20 (349 g/kWh) which is equals to diesel, for B30 (361 g/kWh), B40 (369 g/kWh), B50 (375 g/kWh) is respectively 3.4%, 5.7%, 7.5% higher than diesel. As it is clear BSFC for B20 is same as that of diesel. The reason may be due to high viscosity higher volumetric fuel delivery of fuel per stroke of the engine. Another reason may be due to presence of inherent oxygen is dominating over lower NCV for better combustion. However, beyond B20, the lower NCV is the dominating factor over inherent oxygen presence.

B. BSFC for Blends of JCO and Diesel

The engine performance has also been evaluated using blend of Jatropha oil and diesel. It is found that thee blends having up to 40% amount of Jatropha oil with diesel can be used for operating IC engine beyond which engine could not be started. The trend of BSFC for different blends of Jatropha oil with diesel is shown in fig.2, which indicates that the highest BSFC for B40 (407 g/kWh) at full load is about 17% higher than diesel (349 g/kWh) due to the lower calorific value of blend than diesel (around 16-17%).



C. Fig.2 Variation in BSFC for Blends of JCO and Diesel

As the BSFC is depends on fuel specific gravity, viscosity and NCV therefore as the specific gravity increases and NCV decreases, more fuel is required to produce the same power output. Further it is observe that with increase of Jatropha oil in the blend, BSFC also increases as shown by the results, in which BSFC for B10 (355 g/kWh), B20 (374 g/kWh), B30 (379 g/kWh) is respectively 2%, 7.2%, 9% higher than diesel. This means that higher amount of biodiesel is required for getting the same power output as obtained from diesel alone.

D. BSFC for Blend of JCO and Methanol

As the process of production of biodiesel from Jatropha oil has been optimized with respect to 30% methanol mixed with TG for the transesterification reaction. Since transesterification is more time consuming and therefore it is easier to prepare the blends of methanol with Jatropha oil in 30% (v/v) has been used to operate the engine. The trend of BSFC for blend of Jatropha oil with methanol is shown in fig.3, which indicates that the BSFC is (449 g/kWh) 28.6 % higher than that of diesel (349 g/kWh).

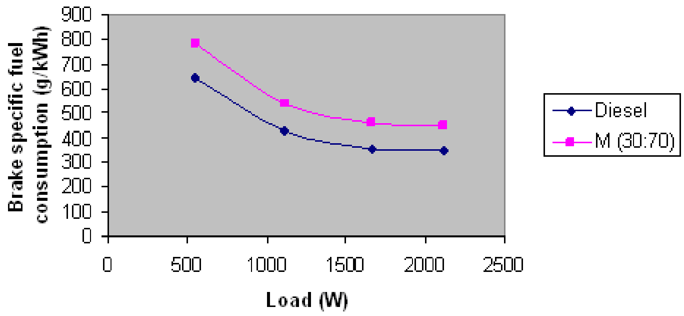


Fig. 3 Variation in BSFC of JCO and Methanol

The reason for this is lower calorific value of blend than diesel (around 25-27%). As the BSFC is depends on fuel specific gravity, viscosity and NCV therefore as the specific gravity increases and NCV decreases, more amount of fuel is needed to produce the same amount of energy.

E. BTE for Blends of JCB and Diesel

The variation of brake thermal efficiency is shown in the fig.4, which indicates that the Brake Thermal Efficiency of JOME (24%) is almost same as that of diesel at full load.

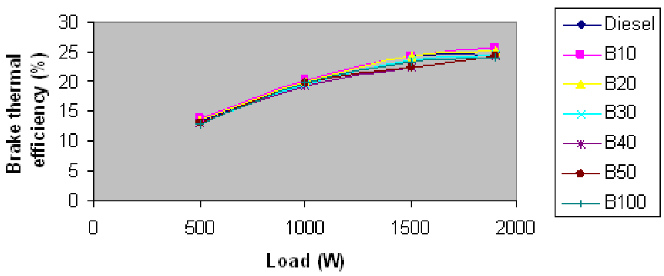


Fig.4 Variation in BTE with Load for Different Blends of JCB with Diesel

The brake thermal efficiency for biodiesel for all blends range (from B10 to B100) was found almost comparable to that of diesel fuel. Perhaps due to higher cetane number and inherent presence of oxygen in the biodiesel produced better

combustion. In addition the JOME and blends have lower viscosity and density than SVO. The reduction in viscosity of JOME leads to improved atomization, fuel vaporization and combustion. The ignition delay time is also close to diesel with ester as the cetane rating is higher. The brake thermal efficiency for B10 (25.8%), B20 (25.2%) and B30 (24.6%) was found about 1.3%, 0.7% and 0.1% higher than diesel respectively. The reason for higher efficiency up to B30 may be because of better combustion due to inherent oxygen and higher Cetane number. Beyond B30, the lower calorific value and higher viscosity might be dominating factor responsible for poor atomization of fuel in the engine cylinder.

F. BTE of Blend of JCO and Diesel

The variation of brake thermal efficiency of various blends of JCO and diesel is shown in the fig.5, which indicates that the Brake Thermal Efficiency of blend of Jatropha oil and diesel (21.7%) is almost 2.8% less than that of diesel at full load.

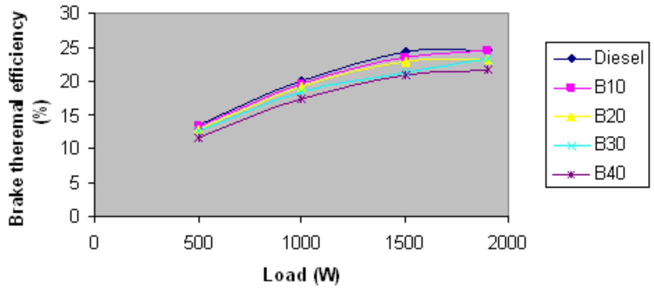


Fig.5 Variation in BTE with Load for Different Blends of JCO with Diesel

The reason may the lower calorific value and higher viscosity might be dominating factor over inherent oxygen and higher Cetane number. Due to higher viscosity, the atomization of fuel has not been as good as it is for lower viscosity at same level of pressure developed by injector pump.

G. BTE of Blend of JCO and Methanol

The variation of brake thermal efficiency of blend of Jatropha oil and methanol is shown in the fig.6, which indicates that the Brake Thermal Efficiency of blend of JCO and methanol (22.4%) is almost 2.1% less than that of diesel at full load.

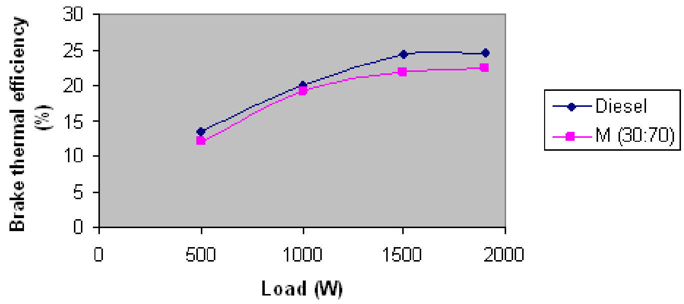


Fig.6 Variation in BTE with Load for Different Blends of JCO with Methanol

But at the same time it is 3.1% higher than that of blend of Jatropha oil and diesel (21.7%). Blends of Jatropha oil and methanol have lower viscosity and density than SVO and diesel blend. The reduction in viscosity helps to improve the atomization, fuel vaporization and combustion. The thermal efficiency of blends has improved due to faster burning of methanol in the blend. The reason being the rise in the heat release rate due to rapid combustion of methanol by flame propagation. The thermal efficiency has increased compared to raw JCO and blends of JCO with diesel.

V. CONCLUSIONS

Biodiesel, produced from renewable and often domestic sources, represents a more sustainable source of energy and will therefore play an increasingly significant role in providing the energy requirements for transportation. Therefore, more and more researches are focused on the biodiesel engine performances and

Its emissions in the past 10 years. Although there have always been inconsistent trends for biodiesel engine performances and its emissions due to the different tested engines, the different operating conditions or driving cycles, the different used biodiesel or reference diesel, the different measurement techniques or instruments, etc., the following conclusions could be drawn according to analysis and summary of the present experimental work:

- The engine performance evaluation has found that brake specific fuel consumption for B_{100} was 14.8% higher than diesel for biodiesel from Jatropha oil, thereby indicating the use of 100% biodiesel can produce same output of energy using higher amount of biodiesel and therefore both deserve to become the "On Farmer Fuel" where farmer can grow his own resource, convert to biodiesel and use in agricultural sets itself without the need of any diesel for blending.
- The brake specific fuel consumption for B_{10} blend was 4% higher than diesel for biodiesel from Jatropha oil at full load while B_{20} gave the BSFC similar to diesel showing that energy contents of both the blends and diesel are almost same.
- The brake thermal efficiency is found higher upto B_{30} in comparison to diesel while BTE of B_{100} (24%) was almost equals to diesel (24.5%) for JOME.

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